

## Chemical Contamination of California Drinking Water

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*Drinking water contamination by toxic chemicals has become widely recognized as a public health concern since the discovery of 1,2-dibromo-3-chloropropane in California's Central Valley in 1979. Increased monitoring since then has shown that other pesticides and industrial chemicals are present in drinking water. Contaminants of drinking water also include naturally occurring substances such as asbestos and even the by-products of water chlorination. Public water systems, commercially bottled and vended water and mineral water are regulated, and California is also taking measures to prevent water pollution by chemicals through various new laws and programs.*

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Patients concerned about the health risks of contaminated groundwater may seek advice from their physicians. This review is intended to assist physicians in responding to such questions. It will cover groundwater and surface water contamination and the scientific basis of regulatory standards.

The vulnerability of groundwater to chemical contamination by pesticides was most dramatically revealed by the 1979 discovery of the pesticide 1,2-dibromo-3-chloropropane (DBCP) in the Central Valley of California. Like other soil fumigants, DBCP was injected into the soil to kill nematodes. Since 1955 about 1.4 million kg (3 million lb) of DBCP was being applied annually in California before its use was suspended in 1977 following findings of sterility or reduced sperm counts in male workers at a formulating plant.

In California about 2,500 wells have been found to be contaminated with DBCP; more than half of these wells have been made unusable as a drinking water source because DBCP concentrations exceed the state health advisory guideline (action level) of 1 part per billion (ppb; parts per billion =  $\mu\text{g}$  per liter).<sup>1(p54)</sup> DBCP has also been found in wells in Arizona, South Carolina, Maryland and Hawaii. Its widespread occurrence and persistence in groundwater—one study estimates its half-life in soil at 141 years<sup>2</sup>—underscore the need for prevention rather than cleanup.

Monitoring for pesticides and industrial chemicals in drinking water has greatly increased in California since 1979. The California State Water Resources Control Board has verified 441 cases of groundwater contamination by 54 different pesticides in 28 counties, not including the DBCP cases.<sup>1(p66,77)</sup> Many of these incidents may have come from spills or the improper disposal of pesticides rather than from agricultural use.<sup>1(p66)</sup>

No single inventory of industrial chemical groundwater contamination incidents exists, but the results from the sampling of wells of large public water systems prompted by California's AB 1803 program show that 18.3% of the wells had some contamination and 5.6% exceeded one or more state standards.<sup>3</sup> These public water system wells were mostly deep and therefore less likely to be contaminated by pesti-

cides. About 41% of the contaminated wells were in Los Angeles County, which indicates that industrial sources such as storage tanks, improper holding ponds, leaking sewers and even parking lot runoff are major sources of contaminants. Before further discussing water contaminants and their health effects, however, an understanding of standards and regulations will help.

### Regulatory Programs and Standards

Under the authority of the Safe Drinking Water Act (PL 93-523), the Environmental Protection Agency (EPA) has had national authority since 1974 over drinking water quality and the regulation of public drinking water systems, but states may create and administer their own safe drinking water programs if they meet minimum EPA standards. The California Safe Drinking Water Act states that water delivered by public water systems in the state shall "be at all times pure, wholesome, and potable."<sup>4</sup>

To ensure drinking water quality, the EPA (or the states) sets standards for contaminants in drinking water, called maximum contaminant levels (MCLs). These standards seek to protect public health while taking into account the economic costs and technologic feasibility of treating or removing the contaminants. MCLs are divided into two categories: primary, for chemicals that have adverse health concerns, and secondary, for those that have mainly aesthetic effects—that is, taste, odor and appearance of the water. MCLs are legally enforceable standards. The EPA has established few MCLs in the past. Until recently, primary MCLs covered only ten inorganic and seven organic chemicals plus radionuclides. Because of the delay at the federal level and unique contamination issues in California, the California Department of Health Services (CDHS) sets certain MCLs of its own.

When contaminants without MCLs are detected in drinking water supplies, the EPA and some states develop nonenforceable health advisory guidelines (called action levels in California). The guidelines help distinguish between hazardous and nonhazardous exposures and prompt water utilities to notify customers and to take corrective measures

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## ABBREVIATIONS USED IN TEXT

CDHS = California Department of Health Services  
 DBCP = 1,2-dibromo-3-chloropropane  
 EPA = Environmental Protection Agency  
 MCL = maximum contaminant level  
 ppb = parts per billion  
 THM = trihalomethane

when action levels are exceeded. Though public notification of action level excesses used to be voluntary, the CDHS now requires large water suppliers to notify customers whenever action levels or MCLs are exceeded. Recent legislation (AB 1803) requires water suppliers to monitor wells for all chemicals that are used in the area of the aquifer rather than just for chemicals with MCLs, as was previously required. The CDHS is also developing action levels for all new contaminants detected in drinking water systems, as well as evaluating health effects of contaminants found in private wells.<sup>3</sup>

To establish standards, toxicologists consider the data on acute and chronic effects, neurotoxicity, teratogenicity, mutagenicity and carcinogenicity. With noncarcinogenic contaminants, scientists often recommend that the standard be set at a level 10, 100 or even 1,000 times below the "no-observed-adverse-effect" level determined from experiments in animals to include a safety margin or uncertainty factor. This safety factor reflects possible differences between animal species and humans and differences in susceptibility in humans. It may be increased when there are uncertainties in the available toxicologic data, such as when the no-observed-adverse-effect level has not been determined. Exceeding an MCL or action level indicates an encroachment into the margin of safety but does not necessarily indicate an endangerment of public health.

Because of the nature of the carcinogenic process, however, no-observed-adverse-effect levels are generally nonexistent. Carcinogenesis is believed in many cases to involve the

interaction of a carcinogen with DNA or other target macromolecules, and cancer can ensue from this event within a single cell.<sup>5,6</sup> Regulatory agencies, therefore, generally consider carcinogenesis to be a nonthreshold process.

Mathematical models are used to assess cancer risks. Because only 100 or fewer treated animals per sex per species are usually used in experiments, the doses must be high enough to produce statistically meaningful results but not so great as to produce adverse effects other than tumors, such as toxicity or low weight gain. From the data points at the high experimental doses, a curve is extrapolated downward to estimate what effects would occur at the very low doses found in environmental exposures. Using high doses to determine effects of chemicals that normally exist at very low levels in the environment is controversial.

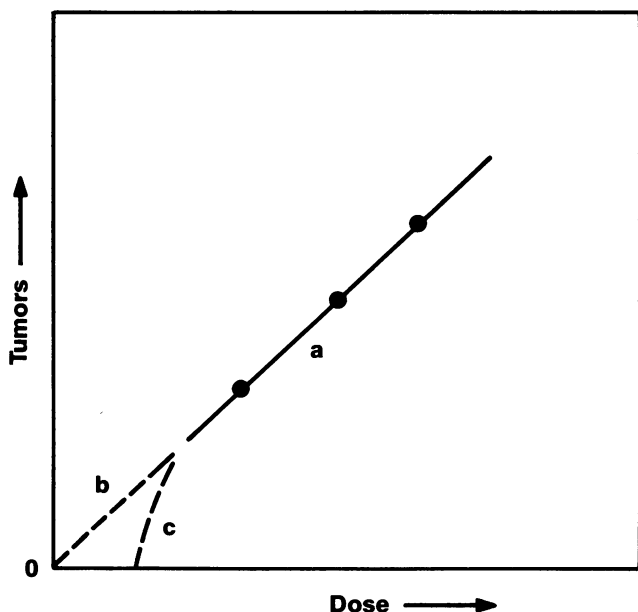
Figure 1 shows the difference between the threshold and nonthreshold models.<sup>7</sup> The curve on the graph is simply for illustration; more complex functions are used in extrapolating low-dose effects.<sup>5</sup> The National Research Council's Board on Toxicology and Environmental Health Hazards recommends that "as a general rule, nonthreshold models should be used" for carcinogens except when evidence from animal experiments shows otherwise.<sup>8</sup>

### Setting Standards for Carcinogens

Whenever feasible, standards and action levels for carcinogens are established as "acceptable" or *de minimis* risk. The EPA has established the upper limits of acceptable risks between one additional case of cancer in a population of 100,000 to one in 1 million ( $10^{-5}$  to  $10^{-6}$ ) over a 70-year lifetime.<sup>9</sup> Similarly, the CDHS considers risks at the one-in-a-million level or below to be negligible. This risk level is intended to be health conservative because it involves involuntary risk. Public health officials believe that although society willingly accepts much higher voluntary risks, it will not tolerate similar risks for someone else's economic benefit.

One risk assessment study of the drinking water in 25 cities has noted that contaminants in drinking water are usually present in mixtures and that the aggregate risks from these mixtures in most of the cities studied "are comparable to other risks that society puts up with but tries to control."<sup>10</sup> In drinking water found to have a high aggregate risk, such as 2.5 persons per 1,000, most of the risk was due to the presence of the by-products of chlorination.

Another approach to determining the health effects of contaminants in water is through epidemiology, but only a few studies have been done of synthetic organic chemicals in drinking water. Nearly all of these investigations have been on cancer risk and most have been aggregate-risk studies in which geographic areas are the units of observation rather than people.<sup>11</sup> Aggregate studies can be done more rapidly because public data sources usually provide the necessary information on cancer mortality, but inherent problems such as variations in individual exposure within an area and potential confounders make inferences of causation difficult. Shy concluded that although aggregate studies can be useful in justifying more costly epidemiologic investigations of exposed persons, large case-control interview studies are needed to clarify causal relationships.<sup>11</sup> One such study, as noted later, has been conducted in Santa Clara County by the CDHS, and another has been carried out in Woburn, Massachusetts, where an excess prevalence of childhood leukemia has been investigated.



**Figure 1.**—The concept of threshold versus no threshold is shown by the extension of line *a* to 0 dose: solid line *a* is an experimentally determined dose response from high doses, dashed line *b* is a downward extrapolation showing a nonthreshold effect using the one-hit model of carcinogenesis and dashed line *c* shows a threshold effect (modified from Van Duuren and Banerjee<sup>7(p87)</sup>).

### Pollution Implications

Drinking water action levels are not set as limits for pollution—that is, as permits for contamination up to the health-based level. Drinking water standards indicate when contamination levels in drinking water have reached such an unacceptable level that alternate water sources should be considered or the water treated to protect human health. Action levels do not reflect environmental bioaccumulation in plants and animals, the fate and toxicity of chemical degradation products or human exposure to the interaction of complex chemical mixtures in various media. The federal Clean Water Act and state laws deal with protecting water from pollution.

### Agricultural Contaminants

#### Fumigants

DBCP is the most widespread pesticide contaminant in groundwater in California and the United States. Many wells in California's Central Valley have been contaminated with DBCP concentrations above the California action level of 1 ppb. DBCP is known to cause sterility in exposed workers and testicular atrophy in test animals and may be a carcinogen for humans as well.<sup>12,13</sup> California's action level, established in 1979, was based on the limitations of the laboratory analytic methods at that time. This level will probably be lowered considerably when California establishes a maximal contaminant level for DBCP. The CDHS has estimated the lifetime risk from consuming 1 ppb of DBCP to be 670 additional cases per million exposed population.<sup>14</sup>

In 1982 the CDHS, using census tracts, did a descriptive epidemiologic study of selected cancer mortality compared to DBCP drinking water contamination levels in Fresno County for 1970-1979. The study noted statistically significant trends of increasing stomach cancer and lymphoid leukemia with increased DBCP levels in water.<sup>15</sup> The conclusion was that mortality data alone, as used in this study, could not be relied

on to implicate DBCP in drinking water as a cause of cancer, and it was suggested that further studies be done in which the data could be better controlled to separate out the confounding factors such as socioeconomic status and ethnicity.

After DBCP was suspended from use in 1979, the use of other fumigants increased, and now most have also been detected in wells, including 1,2-dichloropropane, 1,3-dichloropropene and ethylene dibromide (Table 1). The California Department of Food and Agriculture is seeking to limit the 1,2-dichloropropane content of Telone—the one product remaining on the market that contains it—from its present 35% level to only 0.5%. Action was taken to suspend the use of ethylene dibromide as a fumigant in California when it was detected in groundwater and in grain products in 1984. Because ethylene dibromide is so potent a carcinogen in animals, the CDHS maintains that any confirmed findings of the chemical in wells at or above the California action level of 20 parts per trillion (or nanograms per liter), the current detection limit, warrant recommending the use of alternate sources of drinking water.<sup>16,17</sup>

The main fumigant now in use is methyl bromide,<sup>18</sup> which is also under investigation for carcinogenicity.<sup>19</sup> Methyl bromide is often used in combination with chloropicrin. If methyl bromide and other chemical fumigants are found unacceptable due to adverse effects on health and the environment, there will be few registered alternative chemicals left for controlling nematodes.

#### Herbicides

Herbicides, the most heavily used of agricultural pesticides, have polluted surface water and groundwater. Rice herbicides, for example, have contaminated the Sacramento River, which serves as a drinking water source for Sacramento. Complaints about a bitter taste in the city water were correlated with the detection of the herbicides thiobencarb

TABLE 1.—Agricultural Chemicals

Chemical	Use	MCL or Action Level	Main Health Effects	Status
1,2-Dibromo-3-chloropropane . . .	Soil fumigant nematocide	1.0 ppb, Calif; 0.02 ppb, Hawaii (detection level)	Suspected human carcinogen, sterility in more highly exposed men	Suspended 1977—California, banned 1979
1,2-Dichloropropane (1,2-D) . . .	Soil fumigant nematocide	10 ppb, Calif	1,2-D and 1,3-D are components of D-D and Telone; cancer bioassay of commercial mixture in rats and mice positive*	Shell has withdrawn D-D formula nematocide; state seeks to limit 1,2-D in nematocides to 0.5% (from 35% now)
1,3-Dichloropropene (1,3-D) . . .	Soil fumigant nematocide	None set		
Ethylene dibromide . . . . .	Soil fumigant nematocide	20 ppt (detection limit)	Potent animal carcinogen; suspected human carcinogen†	Banned as fumigant; water consumption inadvisable if detected
Methyl bromide; chloropicrin . . .	Soil fumigant nematocide	None set	Methyl bromide undergoing carcinogenicity testing; chloropicrin (tear gas) is acutely toxic	Often used together; these are main fumigants in use now
Molinate (Ordran) . . . . .	Rice herbicide	20 ppb	Low acute toxicity	Detected in Sacramento, Calif, city water
Thiobencarb (Bolero) . . . . .	Rice herbicide	10 ppb (health), 1 ppb (taste)	Low acute toxicity	Detected in Sacramento, Calif, city water
Bentazon ( Basagran) . . . . .	Herbicide	8 ppb	Low acute toxicity; other effects under evaluation	Detected in Sacramento, Calif, city water
Simazine . . . . .	Herbicide	150 ppb	Low acute toxicity	Found in some water systems
Atrazine . . . . .	Herbicide	15 ppb	Low acute toxicity	Found in some water systems
Nitrate . . . . .	Fertilizer waste product	45 ppm	Methemoglobinemia in infants	Problem in some agricultural areas

MCL=maximum contaminant level, ppb=parts per billion, ppm=parts per million, ppt=parts per trillion

\*From the National Toxicology Program, US Dept of Health and Human Services.<sup>16</sup>

†From report to California Air Resources Board, 1984.<sup>17</sup>

(Bolero) and molinate (Ordram) in the city's water.<sup>20,21</sup> Because the consumer complaint and sampling data show the taste detection limit for thiobencarb to be about 1 ppb, the CDHS took the unusual step of setting a secondary action level of 1 ppb for thiobencarb, ten times below the primary health protection level, to prevent aesthetic degradation of the drinking water. Another herbicide more recently detected in the Sacramento River is bentazon (Basagran), for which the CDHS has set an action level of 8 ppb.<sup>22</sup> Controls on herbicide use have resulted in reducing the herbicide levels in the city's water and general compliance with the action levels.<sup>23</sup>

Herbicides that have been detected in groundwater include simazine, atrazine, bromacil, prometon and diuron.<sup>24</sup> Action levels have been established for the first two of these. None of these herbicides have been found at concentrations that cause health concerns.

### Nitrate

Nitrate is California's major groundwater pollutant. It enters the water supply through nitrogen-containing fertilizers, feedlot wastes and failed septic systems. A 1983 survey of small water systems in California found 238 violations of the 45 ppm maximum contaminant level (ppm = mg per liter), with levels ranging up to 228 ppm.<sup>25</sup> At high levels, nitrate through conversion in the gut to nitrite can cause methemoglobinemia, a hazard to infants younger than 6 months.<sup>26</sup> The CDHS advises that bottled water be used in preparing infant formula whenever the nitrate levels in drinking water are found to exceed the MCL. Boiling is not effective for removing nitrate or other nonvolatile substances from water.

In an epidemiologic study, a possible association was found between nitrate in drinking water and neural tube de-

fects in infants in South Australia, but there is no evidence for a cause and effect relationship.<sup>27</sup> Studies in animals do not suggest that nitrate is a teratogen; further studies are needed, however, for other reproductive effects using updated protocols. Likewise, carcinogenicity data are inconclusive. Some epidemiologic studies have correlated an increased exposure to nitrate or nitrite in the diet or drinking water with an increased prevalence of stomach cancer, but again a causal relationship is lacking. Nitrate conversion in the human stomach to *N*-nitroso compounds, some of which are highly carcinogenic, is known to be possible, but there is no evidence to conclude that nitrates or nitrites themselves are carcinogenic, and data are inadequate to determine the biologic significance of such possible exposure to *N*-nitroso compounds.

### Industrial Contaminants

Volatile synthetic organic chemicals have been widely detected in groundwater. Their uses include cleaning jet engines on military bases and decontaminating microchips in the electronics industry. The EPA has selected them as the first group of chemicals for which it is developing MCLs.<sup>28</sup>

Four such volatile organic chemicals most commonly found in California drinking water systems are tetrachloroethylene or perchloroethylene, trichloroethylene, 1,1,1-trichloroethane and vinylidene chloride or 1,1-dichloroethylene (Table 2).<sup>3</sup> Except for vinylidene chloride, a monomer used in manufacturing plastics, these are industrial solvents. Officials are concerned that some of the volatile organic chemicals cause cancer, but data on this and reproductive effects are mainly from animal studies; data from human studies are limited. Many solvents are able to cross the placenta. One

TABLE 2.—Industrial and Other Contaminants in Drinking Water

Chemical Name	Use	MCL or Action Level	Health Concern	Status
Trichloroethane . . . . .	Industrial solvent	200 ppb, Calif action level; proposed US MCL, 200 ppb	Carcinogen in one mouse study, not in four other studies; no evidence in exposed workers; data inadequate to assess; no significant effects but showed delayed development that was reversible*†	Common contaminant in groundwater
Trichloroethylene . . . . .	Industrial solvent	5 ppb, Calif action level; proposed US MCL, 5 ppb	Probable human carcinogen with low potency; no teratogenicity in animal studies‡	Common contaminant in groundwater
Tetrachloroethylene (1,1-dichloroethylene) . . . . .	Industrial solvent	4 ppb action level	Carcinogen in mice and rats; some evidence in exposed workers; no teratogenicity; possible fetotoxicity at high dose§	Common contaminant in groundwater
Vinylidene chloride . . . . .	Plastics manufacture	6 ppb action level	Evidence of carcinogenicity equivocal; weak, if at all	Common contaminant in groundwater
Total trihalomethanes . . . . .	Water disinfectant by-product	100 ppb MCL	Cancer	Under review by EPA
Fluoride . . . . .	Naturally occurring element	1.4 to 2.4 ppm, Calif; 4 ppm US	Teeth mottling, skeletal fluorosis	Recent change in US MCL under legal challenge
Asbestos . . . . .	Naturally occurring element	None	Cancer	Widespread in drinking water systems
Arsenic . . . . .	Naturally occurring element	5 ppb MCL	Cancer	Elevated in some mineral waters
Selenium . . . . .	Naturally occurring element	10 ppb MCL	Causes deformities in avian and livestock offspring; high levels in humans cause gastrointestinal problems, hair and nail loss	Main concern is environmental contamination

EPA=environmental Protection Agency, MCL=maximum contaminant level, ppb=parts per billion, ppm=parts per million

\*From Epidemiological Studies and Surveillance Section, California Department of Health Services.<sup>30</sup>

†From Schwetz et al.<sup>31</sup>

‡From Environmental Criteria and Assessment Office, US Environmental Protection Agency.<sup>32</sup>

§From the National Toxicology Program, US Department of Health and Human Services.<sup>33</sup>

||From the Community Toxicology Unit, California Department of Health Services.<sup>34</sup>

case of hepatic toxicity in a newborn with exposure to perchloroethylene through human milk has been recorded.<sup>29</sup>

One highly publicized solvent contamination episode in California involved the leak of an estimated 50,000 gallons of mixed solvents, mostly 1,1,1-trichloroethane, from an underground waste storage tank at the Fairchild Camera and Instrument Company in San Jose, California. A well serving a nearby residential community had been contaminated when the leak was discovered in 1981. Residents became concerned over an apparent excess of birth defects in their neighborhood, and the CDHS, at the request of the Santa Clara County Health Department, agreed to conduct an epidemiologic investigation.<sup>30-34</sup>

The CDHS studies released in January 1985 showed that combined birth defects in a census tract served by the contaminated well were about three times higher than in a comparison area and spontaneous abortions were about two times higher. Major cardiac defects in the entire area served by the water company were about 2 1/2 times the county average. The studies, however, were inconclusive because the timing and distribution of these outcomes made the contamination of the water unlikely to have been the cause of the health outcomes. For example, the cluster of cardiac defects was seen extending outside the boundaries of the distribution system of the water company with the contaminated well. Also, available toxicologic data indicate that 1,1,1-trichloroethane is not teratogenic. Moreover, the studies found that the pattern of congenital malformations "is not one that is common for a single teratogen since no specific congenital malformation was responsible for the excess."<sup>30</sup>

Fairchild has settled a multimillion dollar citizens' lawsuit but did not admit guilt. CDHS is continuing further studies. The EPA is also conducting an integrated environmental management project in Santa Clara County with various agencies to examine health risks from contaminants in outdoor air, surface water and groundwater.<sup>35</sup> Preliminary findings indicate that pollutant levels in the Santa Clara Valley are typical of many other urban areas, and the EPA predicts that "under pessimistic assumptions, contamination of groundwater supplies of drinking water could result in one additional case of cancer every 30 years."<sup>35</sup>

Santa Clara County was one of the first governmental agencies to pass an ordinance requiring water pollution safeguards on underground storage tanks. Many old fuel storage tanks are believed to be leaking, and the state and federal governments are now taking steps to protect against leakage from such tanks.<sup>36</sup>

Other areas with significant groundwater contamination in California are the San Gabriel and San Fernando Valleys near Los Angeles, several military bases in the Central Valley and the Aerojet rocket fuel manufacturing facility near Sacramento.

### Naturally Occurring Contaminants

While synthetic or industrial substances have received the most publicity, some naturally occurring substances in water also pose a toxicologic concern. These include asbestos, selenium, fluoride and arsenic (Table 2). Arsenic has been a problem mainly in mineral water.

#### Asbestos

Asbestos comes mainly from serpentine rock, which is found widely in California's coastal ranges and foothills.<sup>37</sup>

Most asbestos settles out in reservoirs or is removed in water treatment plants,<sup>38</sup> but an EPA survey of urban water systems in 365 cities found 41 with asbestos concentrations greater than 10 million fibers per liter.

Studies of cancer in animals ingesting asbestos and epidemiologic studies of populations exposed to drinking water with high levels of asbestos have all been negative. The epidemiologic studies were flawed, however, and a National Research Council committee has found that on reanalysis they produce a relative risk similar to one calculated for gastrointestinal tract cancer based on an occupational exposure to asbestos. The committee estimated that the concentration in water needed to cause a one-in-a-million added lifetime risk of cancer would be a little more than 1 million fibers per liter. Some San Francisco Bay Area water systems have more than 100 million fibers per liter of asbestos.<sup>39</sup>

#### Selenium

Selenium has been linked with deformities and death in chicks of aquatic birds at the Kesterson National Wildlife Refuge (Central Valley, California) where irrigation discharge water had been stored. Selenium, which derives from marine shales, has been found in few large water systems in the state, but a 1983 survey of small California water systems showed 27 violations of the 10-ppb action level, mostly associated with outcroppings of selenium-rich rock.<sup>25</sup>

Selenium has an extremely narrow therapeutic index: either excess or absence of selenium in the diet causes harm. Because of observed reproductive effects in birds and livestock, the teratogenic potential in humans is of obvious concern, but to date no standard assay for this effect of selenium compounds has been carried out. Selenium has not been determined to be carcinogenic.

The CDHS did a health survey among residents in the Kesterson area matched by age and sex with a control population. Results did not show any trend of adverse health effects.<sup>40</sup>

#### Fluoride

Fluoride has great public health benefit in preventing dental caries at dosages of 0.5 to 0.7 ppm in water.<sup>41</sup> The fluoride standard is in controversy, however, because in early 1986 the EPA, as part of a settlement of a lawsuit brought by South Carolina, increased the primary drinking water standard from between 1.4 and 2.4 ppm to 4 ppm to protect against skeletal fluorosis and to set a secondary optional standard of 2 ppm to protect against objectionable dental fluorosis.<sup>42</sup> South Carolina, which wanted to avoid the high cost of removing fluoride from groundwater, initially asked that the MCL be changed to 8 ppm. California has not raised its MCL as dental mottling would occur in almost all children exposed to 4 ppm during tooth development, and because skeletal fluorosis has been observed when drinking water containing only 3 ppm is used (skeletal fluorosis becomes crippling when water levels reach 20 to 40 ppm).<sup>43</sup>

### Contamination From Water Disinfection and Delivery Systems

#### Trihalomethanes

The most common synthetic organic chemicals found in US drinking water are by-products introduced during drinking water treatment to prevent infectious disease. Trihalomethanes (THMs) are produced when chlorine reacts with

natural organic materials in the water. Of these chemicals, chloroform (trichloromethane), a known animal carcinogen, is the most common.<sup>44</sup> (p 68626) Others are bromoform, bromodichloromethane and chlorodibromomethane. In states, including California, that only require disinfection of surface water used for drinking, THMs are seldom found in drinking water from underground sources, but a 1986 amendment to the Safe Drinking Water Act requires that all water be disinfected at the source.<sup>45</sup>

The EPA finds the available epidemiologic evidence for the cancer hazard of THMs in water inconclusive but "at least suggestive of a health risk."<sup>45</sup> and the National Academy of Sciences in a review of 13 preliminary studies concluded that "the risks were small but that important confounding factors could not be distinguished in indirect ecological studies to allow a precise evaluation of the contributions from THMs."<sup>44</sup> (p 68627)

The establishment of an MCL of 100 ppb (0.1 ppm) per liter for total trihalomethanes represents an attempt to balance the risks of cancer against the known benefits of preventing infectious disease transmission. Chlorine is considered the most effective water disinfectant because of its reactivity and its residual effect in the water distribution system. Its efficacy has been proved over many years. The EPA has calculated a risk of about 1 additional case of cancer per 2,500 persons with exposure for a lifetime—or 200 additional cases of cancer per 1 million persons with exposure—to the total THMs at the maximum contaminant level based on the extrapolated chloroform risk.<sup>44</sup> (p 68704)

Chloramines are the main alternative water disinfectant used. Chloramines produce fewer THMs, but they are less effective than chlorine. They must be removed from water at kidney dialysis facilities because they can damage erythrocytes. Chlorine dioxide and ozone are other disinfectants, and all of these disinfectants are oxidants and have the potential to form undesirable by-products, the effects of some of which are just being realized.<sup>46</sup>

Trihalomethanes in treated water represent a higher cancer risk than most toxic pollutants at the levels that the latter have been measured in drinking water. The long-term health effects of all the disinfectants have been in question for some time, and the EPA is reexamining them. Trihalomethane levels can be reduced by using carbon treatment either before chlorination to remove organic matter or after to remove the THMs themselves, but this is costly.

### Lead

High levels of lead in water pose a significant hazard to the public, especially to children, who are highly susceptible to its hematologic, renal and neurologic effects. The MCL for lead is 50 ppb, but concentrations in delivery systems are usually less than 10 ppb.<sup>47</sup>

Lead solder used in water distribution lines and occasionally lead pipes and lead-lined storage tanks are the main sources of lead in drinking water. Lead concentration is strongly affected by water pH and hardness as well as by water temperature and the length of time the water sits in the pipes.

No lead concentrations exceeding the EPA drinking water standard have been reported in any main distribution line of California municipal water supplies. Because lead pipes were installed in some California homes in the early 1900s, however, levels exceeding the MCL by several times have oc-

curred in tap water as a result of lead leaching from the pipes and solder.<sup>48</sup>

Concern over the possible subtle neuropsychological effects in children from low-level lead exposure has resulted in new federal and state legislation.<sup>49,50</sup> These laws prohibit using lead solder or flux exceeding 0.2% lead in new installations and repairs or using pipes containing more than 8% lead beginning in June 1988, and they require public water supply systems to notify customers of lead contamination that may cause potential health effects. Notification may be required because of the high corrosivity of water or other factors independent of MCL violations.

### Commercially Bottled Water, Mineral Water, Machine Vended Water and Home Treatment Units

#### *Commercially Bottled and Machine-Vended Water*

Commercially bottled drinking water and machine-vended water must meet the same standards as tap water. Bottled-water producers use a variety of sources for their product, such as springs, wells and public water systems. Bottled or machine-vended water is usually processed in one of three ways: distillation, deionization and reverse osmosis. Water vending machines usually use water from public drinking water systems but treat the water with carbon filtration to remove organic chemicals, chlorine and other organic tastes or odors. The effectiveness of these processes for removing organic chemicals and minerals varies considerably.

#### *Mineral Water*

Mineral water is defined as water containing more than 500 ppm of dissolved solids. It has been exempt from drinking water standards because the minerals are naturally part of the product and because it has not been consumed in high volume due to its taste and high cost. Mineral water quality has historically been regulated by licensing of bottlers on a case-by-case basis, though this may change because of mineral water's growing popularity, especially with its new appeal to the young as an alternative to soft drinks and alcoholic beverages.

#### *Home Water Treatment Units*

Concern over drinking water contamination has led to inquiries about devices to treat drinking water in the home. Until 1986 home water treatment units were not regulated for chemical contaminant removal, but two new California laws prohibit false or misleading advertising and require the adoption of performance standards.<sup>51,52</sup> The EPA has also proposed regulations if such units are to be considered an acceptable alternative to central water treatment.<sup>53</sup> Reverse osmosis, carbon filtration and other methods may be used in home treatment units, but their effectiveness in removing different contaminants varies.<sup>53</sup> (pp 46915-46916) -55

Home water treatment devices have been used in California for many years to remove dissolved solids from the water (for mainly aesthetic purposes). Some of the devices are now being promoted for removing organic chemicals. The Public Water Supply Branch of the CDHS has not encouraged this latter use because drinking water delivered by public water systems already meets (with rare exceptions) state standards or action levels for organic chemicals; there is no program to maintain the units other than an owner's service agreement with the supplier (for example, if the filter breaks

on a reverse osmosis unit, the owner would be unaware of the failure) and secondary problems are inherent in some of these devices, such as bacterial growth on activated carbon filters.

## Preventing Water Contamination

Laws have been passed and programs implemented to prevent further toxicant contamination of drinking water. The EPA and California have started programs to monitor underground fuel storage tanks at automotive service stations and other locations. New tanks will have to be double lined and leaking ones replaced. The EPA estimates that 35% of underground fuel tanks leak.<sup>36</sup>

California law prevents the dumping of hazardous wastes near underground aquifers that may be used as a drinking water source. The California Department of Food and Agriculture and the EPA are obtaining data on the fate of pesticide ingredients in the environment to determine their potential to contaminate groundwater. These data will be used to develop use restrictions in areas where pesticides are likely to pollute groundwater. Also, the new requirement (AB 1803) for small water systems in California to be monitored for chemical contaminants will have an effect on detecting problems at an earlier stage. The EPA has a program for protecting groundwater, but it has been criticized by some as "a regulatory patchwork" and inadequate.<sup>56</sup> The EPA soon plans a pilot survey of pesticides in drinking water wells.

## Assistance for Physicians

When patients have had exposure to contaminated drinking water, their physicians will need to know the substances involved and their concentration levels to be able to advise the patients about possible health outcomes. Local water purveyors should have information about any contaminants in their systems, and local or state health agencies should be able to give information on water standards or how to analyze well water. The CDHS is producing a series of fact sheets on water contaminants and other reviews on toxic issues (for more information, write to the Community Toxicology Unit, Department of Health Services, 2151 Berkeley Way, Berkeley, CA 94704 and request a publication order form). The Toxic-Info Center, which is operated by the San Francisco Regional Poison Control Center, will answer inquiries from California health and emergency professionals and from the public about the toxicity and hazardous properties of chemicals. The center has a toll-free hotline in California (800-233-3360). A new booklet for persons concerned about drinking water in their communities is "Drinking Water—A Community Action Guide," published by Concern, Inc., 1794 Columbia Road NW, Washington, DC 20009. The CDHS is planning a similar booklet written from a California perspective.

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## Book Review

*The Western Journal of Medicine does not review all books sent by publishers, although information about new books received is printed elsewhere in the journal as space permits. Prices quoted are those given by the publishers.*

### Ultrastructural Appearances of Tumors—Diagnosis and Classification of Human Neoplasia by Electron Microscopy

Douglas W. Henderson, MB, BS, FRCPA, Director of Electron Microscopy, Flinders Medical Centre, Adelaide, and Honorary Consultant in Ultrastructural Pathology, The Queen Elizabeth Hospital, Woodville, South Australia; John M. Papadimitriou, BA, MD, PhD, MRCPath, FRCPA, Associate Professor of Pathology, The University of Western Australia, and Consultant in Pathology, Royal Perth Hospital and Queen Elizabeth II Medical Centre, Perth, Western Australia, and Mark Coleman, MB, BS, FRCPA, Senior Staff Specialist in Pathology, Flinders Medical Centre, Adelaide, South Australia. Churchill Livingstone Inc, 1560 Broadway, New York, NY 10036, 1986. 425 pages, \$136.

As with its first edition counterpart, this second edition will prove to be an indispensable addition to the library of anyone involved in the ultrastructural diagnosis of tumors. The authors have done a Herculean task in bringing order to what is often a diffuse and nebulous subject. In organizing the chapter material into organ specific and tumor specific categories, a semblance of order and logic is added to the subject of electron microscopy. Much new material is added on specific organs and tumors not covered in the first edition. Not only are the more common neoplasms included, but the depth of this text is evident to the point that unusual entities such as "anemone" cells and Merkel cell tumor are discussed. A great strength of this text is the ample use of high-quality illustrations. The numerous tables also give fingertip availability of the features of specific tumors as well as a comparison between different tumors. The material is current and the references, numerous. The book is not cheap; however, there is little doubt that it is worth every penny and that it will be invaluable to anyone using the ultrastructural features of tumors as a diagnostic tool.

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